The Tolerance to Fluoroacetate of Geographically Separated Populations of the Quokka *(Setonix brachyurus)*

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ABSTRACT

The tolerance to fluoroacetate of three geographically separated populations of the macropodid marsupial, the quokka (*Setonix brachyurus*) in southwestern Australia is compared in terms of elevation of plasma citrate levels in response to dosing with 1080.

The populations from mainland Western Australia and from Bald Island off the south coast of W.A. are currently in contact with fluoroacetate-bearing plants. These populations have a much higher tolerance to fluoroacetate and are more genetically homogeneous for the resistance than the population on Rottnest Island off the west coast of Western Australia. The latter population has been isolated from contact with fluoroacetate-bearing vegetation from some 5,000-7,000 years, but is much more tolerant than are macropodids in southeastern Australia where fluoroacetate-containing plants are not known to occur.

INTRODUCTION

The compound sodium fluoroacetate (1080), commonly used as a vertebrate pesticide, occurs naturally in 34 species of the legume genera *Gastrolobium* and *Oxylobium,* 33 of which are confined to southwestern Australia (Aplin 1971). The evolution of genetic tolerance to fluoroacetate in species of mammals exposed to this substance in nature has recently been demonstrated (Oliver et al. 1977; King et al. 1978) and some of the biochemical aspects of its detoxification have been elucidated (Mead et al. 1979). This acquired tolerance has been used as a genetic marker in studies to trace past radiations of these species (Oliver et al. 1979) and has emphasized the value of 1080 in Western Australia as a target specific pesticide for the control of sensitive exotic predators such as the fox (Vulpes vulpes) (King et al. 1981). Information on the susceptibility of native fauna to the toxin is essential in order to minimise the risk from pest control programs to non-target species. Fox, feral cat and rabbit control is carried out in areas of Western Australia for the purpose of conservation of a number of species of small to medium-sized native mammals.

This paper compares the tolerance to fluoroacetate of geographically separated populations of the quokka (*Setonix brachyurus*) from mainland Western Australia where toxic species of *Gastrolobium* and *Oxylobium* are wide-spread; from Bald Island, Western Australia where *Gastrolobium bilobum* (heart-leaf poison) is common and from Rottnest Island, Western Australia where fluoroacetate-bearing vegetation does not occur.

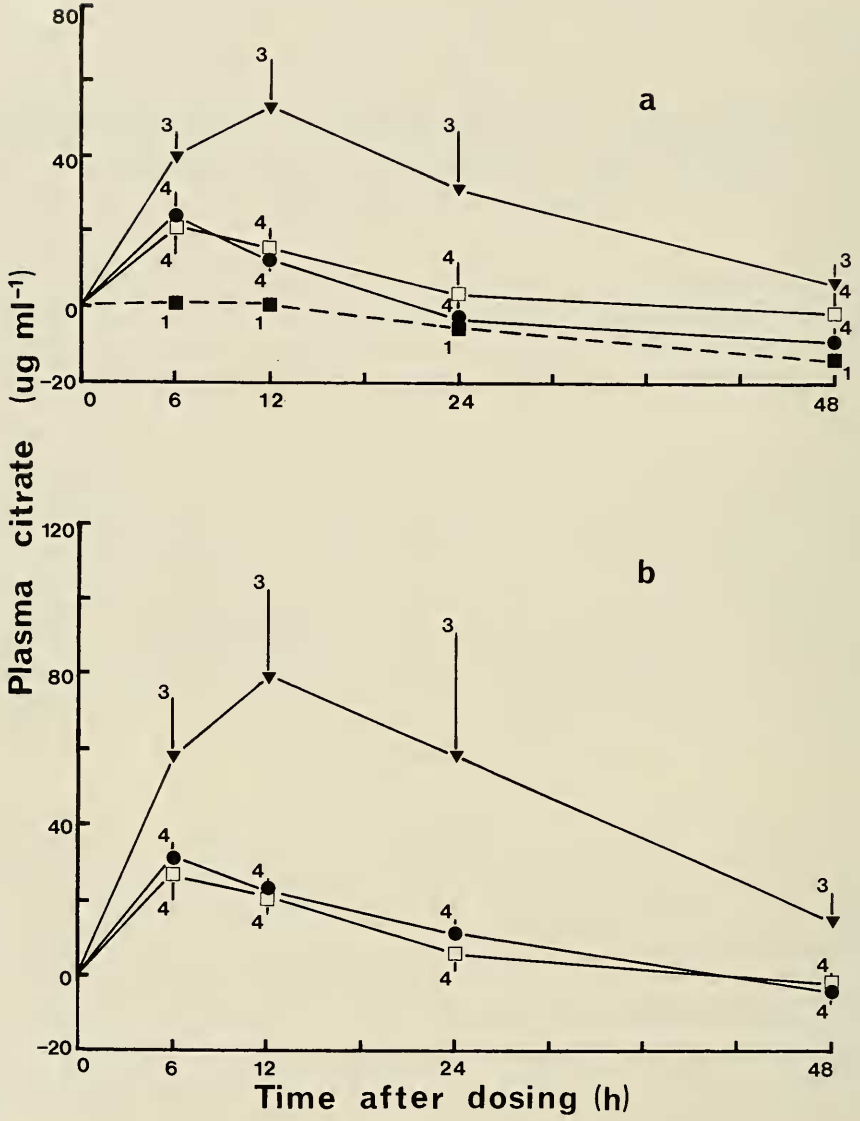

Fig. 1. Mean and Standard Error of the increase above base-level (time zero) values of plasma citrate concentrations following intraperitoneal administration of (a) 3.0 mg 1080 kg^{-1}, (b) 5.0 mg 1080 kg^{-1}, to the Quokka. Symbols: ▼ Rottnest Island, ● Bald Island, □ Mainland Western Australia, ■ Undosed Mainland Western Australia. Numbers beside the symbols represent the number of animals.

MATERIAL AND METHODS

Animals:

Adult *Setonix brachyurus* were collected in the field from localities near Pemberton and Dwellingup on the Western Australian mainland, from Bald Island near Albany, Western Australia, and from Rottnest Island, near Fremantle, Western Australia. Animals were held individually in rabbit cages in animal houses at 22°C and 70% relative humidity and maintained on a 12:12 hour photoperiod. Animals were provided with commercial kangaroo food pellets (Milnes Stock Feeds, W.A.), apples and cabbages. Water was provided ad libitum.

Dosing:

Animals were dosed intraperitoneally with aqueous solutions of commercial grade 1080 (94% sodium monofluoroacetate by HPLC analysis) obtained from Rentokil Laboratories Ltd.

Blood Sampling:

Blood samples for the determination of plasma citrate levels were collected from the lateral caudal vein using heparinized syringes and scalp-vein sets, after warming the tail with hot water to facilitate venipuncturing. Samples were immediately centrifuged and the plasmas frozen and stored at –20°C while awaiting analysis.

Citrate Determination:

As in our previous studies, plasma citrate concentration was determined by the method of Camp and Farmer (1967).

Statistical Analysis:

The elevation in plasma citrate concentration displayed by the three quokka populations after intraperitoneal administration of various doses of 1080 was analysed statistically. To assess significant differences between the three populations within each dose level, a single factor analysis of variance (Keppel 1973) was carried out on the 6 h and 12 h plasma citrate elevations. The Scheffé test was employed to test differences and the harmonic mean was used to compensate for uneven group sizes (Keppel 1973).

RESULTS

Increases in plasma citrate levels following dosing of *S. brachyurus* with various doses of 1080 are shown in Figs 1-3. The increases in plasma citrate concentration in the Rottnest Island population at 3 and 5 mg 1080 kg^{-1} were significantly higher ($p < 0.05$) 12 hours post-dosing than those exhibited by the Bald Island and mainland populations (Fig. 1). The latter two populations did not differ significantly from each other at these dose levels at either the 6 or 12 hour bleeds ($p > 0.05$). Three of the six Rottnest Island animals administered 10 mg 1080 kg^{-1}, died, displaying large elevations in plasma citrate concentration, whereas all Bald Island and mainland quokkas survived doses of both 10 and 20 mg 1080 kg^{-1} (Fig. 2). The latter two populations did not differ significantly from each other 6 or 12 hours post-dosing at either the 10 or 20 mg 1080 kg^{-1} dose level ($p > 0.05$). One of the three mainland animals administered 40 mg 1080 kg^{-1} died 24 hours post-dosing but all Bald Island animals survived (Fig. 3). Citrate accumulation patterns for both populations at this dose level were almost co-incident and did not significantly differ at either the 6 or 12 hour bleed

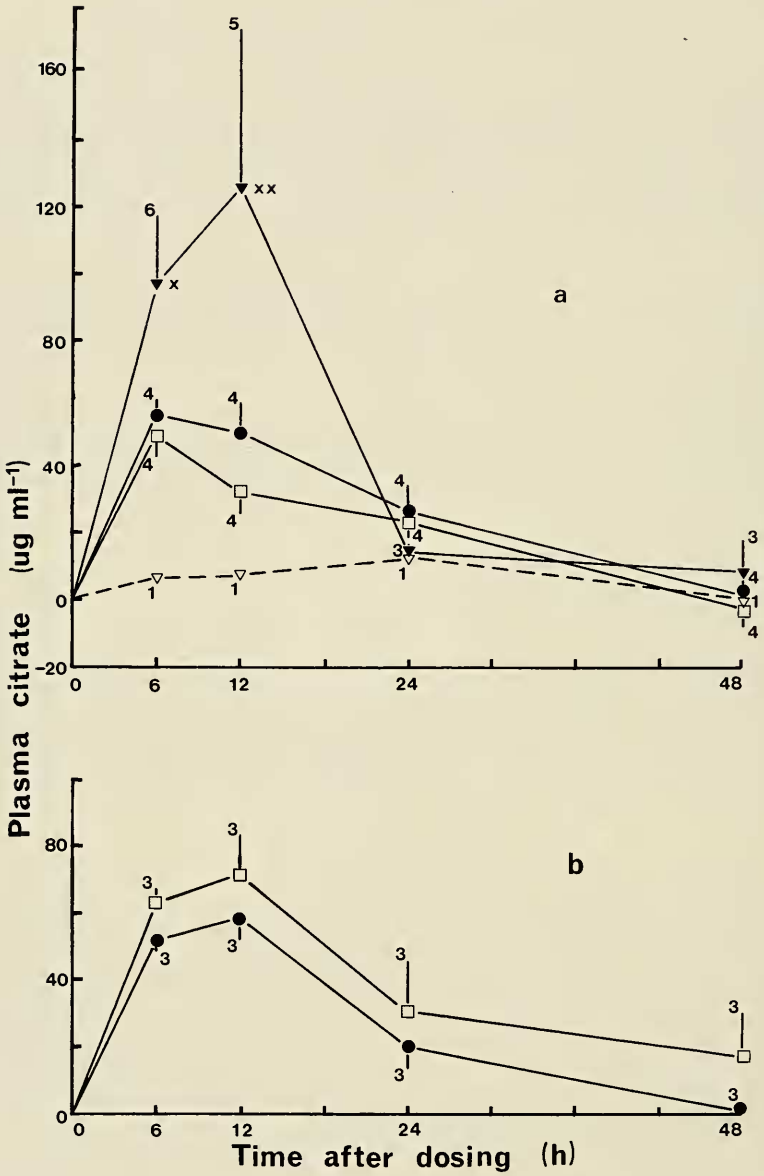

Fig. 2. Mean and Standard Error of the increase above base-level (time zero) values of plasma citrate concentrations following intraperitoneal administration of: (a) 10.0 mg 1080 kg^{-1}, (b) 20.0 mg 1080 kg^{-1}, to the Quokka. Symbols: ▼ Rottnest Island, ● Bald Island, □ Mainland Western Australia, ▽ Undosed Rottnest Island. Numbers beside the symbols represent the number of animals. X indicates death of animal.

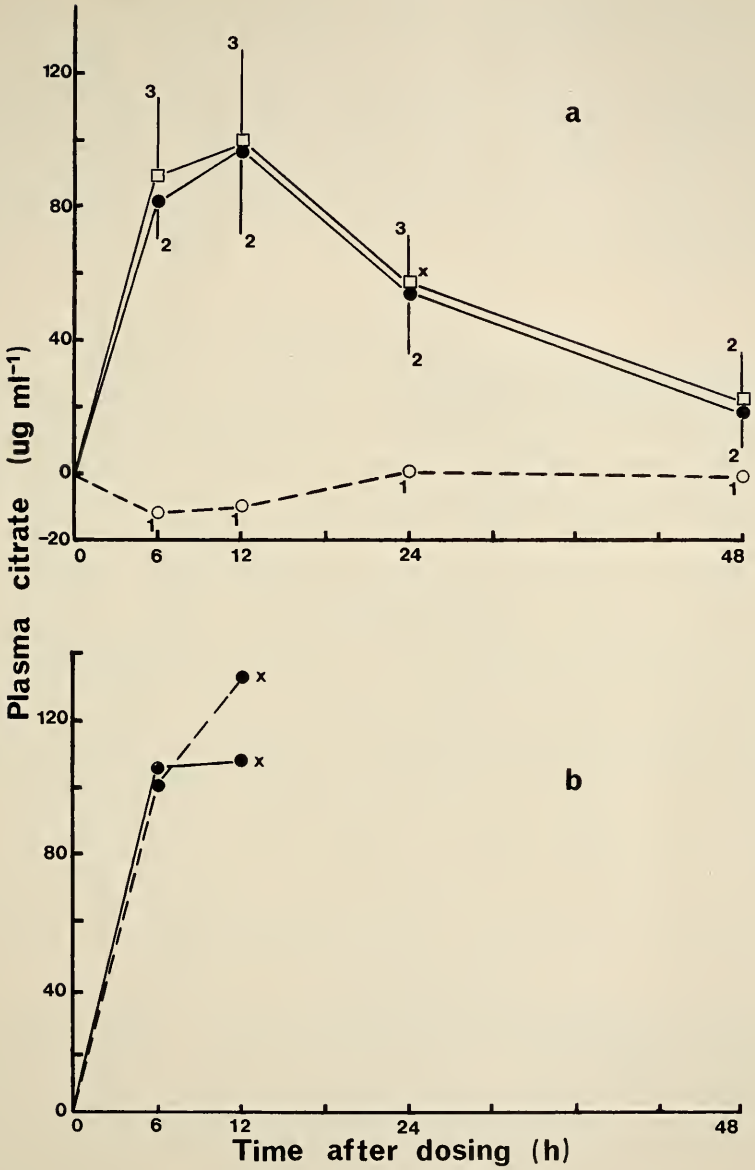

Fig. 3. Increase above base-level (time zero) values of plasma citrate concentrations following intraperitoneal administration of: (a) 40 mg 1080 kg^{-1} (Mean and Standard Error), (b) 60 mg 1080 kg^{-1} (individual animals are shown), to the Quokka. Symbols: ● Bald Island, □ Mainland Western Australia, **O** Undosed Bald Island. Numbers beside the symbols represent the number of animals. X indicates death of animal.

($p > 0.05$). Both Bald Island animals administered 60 mg 1080 kg^{-1} died 12 hours post-dosing showing rapid plasma citrate accumulation (Fig. 3).

The variation in citrate response in individual animals from each of the three populations dosed with 10 mg 1080 kg^{-1} is shown in Fig. 4. The Rottnest Island population displayed more heterogeneity than either of the other populations. Three animals accumulated large amounts of citrate and died, one immediately after the 6 h bleed and two after the 12 h bleed, while the other three animals survived, showing a citrate response typical of the Bald Island and mainland populations (Fig. 4).

DISCUSSION

Elevation of plasma citrate levels in response to dosing has previously been shown to reflect the susceptibility to 1080 intoxication of animals with similar metabolic rates (King et al. 1978). This technique which is more ethically acceptable and more economical than LD_{50} testing is therefore most applicable to the assessment of the tolerance or susceptibility to 1080 of separated populations of conspecifics or of closely related species (King et al. 1981).

The tolerance to 1080 of *S. brachyurus* is similar to that reported for some other endemic south-western Australian fauna (Oliver et al. 1977, 1979; King et al. 1978, 1981) and is substantially higher than that of eastern Australian macropods which have not had contact with fluoroacetate-bearing vegetation (McIlroy 1982). The high tolerance to 1080 of south-western Australian fauna appears to be the result of long-term association with food plants containing fluoroacetate. Though the dietary intake by the quokka of the toxic species of *Gastrolobium* and *Oxylobium* is unknown, another macropodid, the western grey kangaroo (*Macropus fuliginosus ocydromus*) has been shown to consume seven fluoroacetate-bearing species of *Gastrolobium* and *Oxylobium* at most times of the year (Mead 1980). It also appears that the grey kangaroo may have learnt to limit its intake of the most toxic species and to consume larger amounts of the least toxic thus achieving a balance between adequate nutrition and the avoidance of being poisoned (Mead *et al.* 1985).

The Bald Island and mainland populations of *S. brachyurus* appear to have a similar tolerance to 1080 with an LD_{50} value apparently in the region of 40-60 mg 1080 kg^{-1}. Palaeontological studies have shown that *Setonix* was abundant in south-western W.A. at least 30,000 years BP (Merilees 1967, 1979; Balme et al. 1978). As it is probable that the capacity to produce fluoroacetate evolved once many thousands of years ago in a south-western form ancestral to the 34 present day fluoroacetate-bearing species of *Gastrolobium* and *Oxylobium,* it is likely that *Setonix* has been exposed to fluoroacetate for a long period of time. Bald Island became separated only 9,000 years ago (Main 1961) from a mainland region where heavy non-alkaline soils support the growth of toxic species of *Gastrolobium* and *Oxylobium* (Aplin 1971). One might expect that

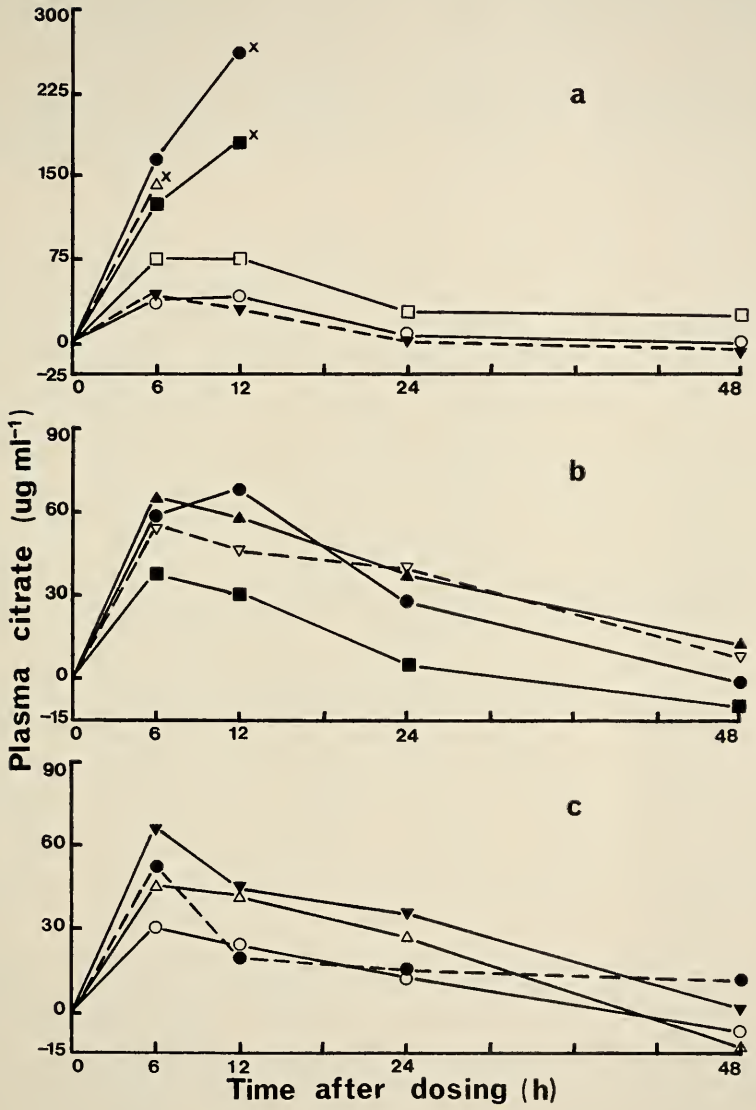

Fig. 4. The increase above base-level (time zero) values of plasma citrate concentrations for individual animals from three Quokka populations following intraperitoneal administration of 10 mg 1080 kg $^{-1}$. (a) Rottnest Island, (b) Bald Island, (c) Mainland Western Australia. X indicates death of animal.

a population isolated on an island would be more frequently forced to rely on a particular food item than would a population on the mainland but the similarity in tolerance to fluoroacetate of the Bald Island and mainland populations suggests that the former population is no more reliant on the leaves of *Gastrolobium bilobum* than is the latter. Bald Island has a mild, moist climate and supports a relatively abundant and diverse flora (Abbott 1981). As the quokka is known to accept a wide range of dietary items (Storr 1964) it is conceivable that food choices on the Island are relatively plentiful even in summer and that extensive reliance on *G. bilobum* is not necessary.

All Rottnest quokkas dosed with 5 mg 1080 kg^{-1} survived (Fig. 1). This suggests that the LD_{50} value of 2 mg 1080 kg^{-1} based on our pilot dosing of animals from Rottnest Island, and cited by McIlroy (1982) was an underestimate. Three out of six animals from the Rottnest Island population survived 10 mg 1080 kg^{-1} suggesting that the LD_{50} may be closer to this value (Fig. 2).

The quokka population on Rottnest Island has not been exposed to fluoroacetate-bearing vegetation since separation of the island from the mainland about 5-7,000 years ago (Churchill 1959; Main 1961) and is likely to be descended from a population occupying the currently adjacent mainland and the intervening land surface which is now submerged. The habitat suitable for quokkas in this region is unlikely to have been suitable for the establishment of the toxic species of *Gastrolobium* and *Oxylobium* due to the presence of deep sands and limestone soils (Aplin 1971). This previous coastal population may therefore have differed in tolerance from the predecessors of the more southerly population, exposed to fluoroacetate-bearing vegetation from which our mainland animals were derived and from which our Bald Island animals appear to have originated. It seems likely that the genetic composition of this coastal population would have been heterogeneous with respect to fluoroacetate tolerance for the reason previously suggested to explain the heterogeneity in coastal populations of *Rattus fuscipes* (Oliver *et al.* 1979): namely a population which has not been selected for tolerance to fluoroacetate receiving a genetic contribution from more tolerant inland populations. The current heterogeneity of the Rottnest Island population (Fig. 4) may therefore reflect this situation.

The tolerance to fluoroacetate of mainland and Bald Island quokkas is sufficiently high and homogeneous to allow 1080 to be used for the control of introduced pests with little risk to these quokka populations. The lower tolerance and greater heterogeneity of the Rottnest Island population would make such a control program more difficult to implement but appropriate choice of bait material and 1080 content could still allow pest control programs to be carried out successfully.

This example of coevolution between animals and toxic plants illustrates how naturally occurring resistance to the toxins can be used to improve target-specificity in control programs directed at introduced pest species and provides

further evidence for the impact of fluoroacetate-bearing vegetation on the genetic composition of mammal populations in the south west of Western Australia.

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